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Fire Making Fuel: How a Surface Fire in a Primary Forest Affected the Availability of Potential Fuel One Year Later

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SIT Study Abroad

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Abstract:

Fires affect millions of hectares of tropical forests around the world. These fires result in great environmental damage and economical losses. Many farmers are dependant on fire for managing their lands and many times their fires accidentally spread into forests via fuels on the forest floor. This study attempted to analyze and quantify the difference of potential fuel in a primary forest which burned one year before and an unburned part of the same forest at a primary forest fragment surrounded by farms and with a history of anthropogenic accidental fires burning it. This was done by making three sample plots in each forest to record the amount of woody materials that cross a linear transect which was made in the shape of an equilateral triangle and recording the depth of leaf litter on the forest floor every five meters. Also, because the fire noticeably left the burned forest in several differently looking states the three samples were of three differently looking forest type in the burned forest and were compared to understand the significance of the differentiation. The study found the burned forest on average had significantly more available woody material than the unburned forest and most of the additional material the burned forest had was found between 0.5 and 2 meters above the ground; although, the burned forest had an average leaf litter depth of less than 74 percent compared to the unburned primary forest. However, the study was unable to find a significant difference in the three samples in the three structurally different areas of the burned forest when it was found that there was more of a variation in between the three sample plots in the seemingly structurally similar primary forest.

Resumo:

Fogos afetam milhões de hectares das florestas tropical em volta do mundo. Esses fogos resultam em danos ambeintal e perdas econômico. Muitos fazendeiros são dependente por fogo administrar os terras deles e muitas vezes os fogos eles usem espalham acidentalmente em florestas através de chão da floresta. Este estudo tentadou analisar e quantificar a diferença do combustível potencial em uma fragmento preliminary da floresta cercado com fazendas com um histórico dos fogos antropologica acidentais que o queimam. Isso foi feito fazendo três lotes da amostra em cada florest tipo assentar a quantidade de materiais de madeira cruzando um transceto linear que foi feito em uma triângulo equitativo e assentando a profundidade da maca da folha no chão da floresta cada cinco metres. Também, porque o fogo deixou visivelmente a

floresta queimada em muitos estados pareçando diferentemente as três amostras de cada tipo de floresta foram comparados compreender o significado do diferenciacão. Este estado encontrou que a floresta queimada na media teve material de madeira significativamente mais disponível do que a floresta não quiemada e o mais do material adicional foi encontrado entre 0.5 e 2 metres acima da terra; também a floresta quiemada teve um media de maca de folha de menos do que 74 por cento comparado à floresta preliminar que é não quiemada. De qualquer modo, o estudo era incapaz encontrar uma diferença significativa nas três amostras nas três estrutural areas diferentes da floresta quiemada quando o era encontrrado que lá foi mais de um variacão entre as três amostras na floresta preliminary se-melhante estruturalmente aparentemente do que os amostras na floresta queimada.

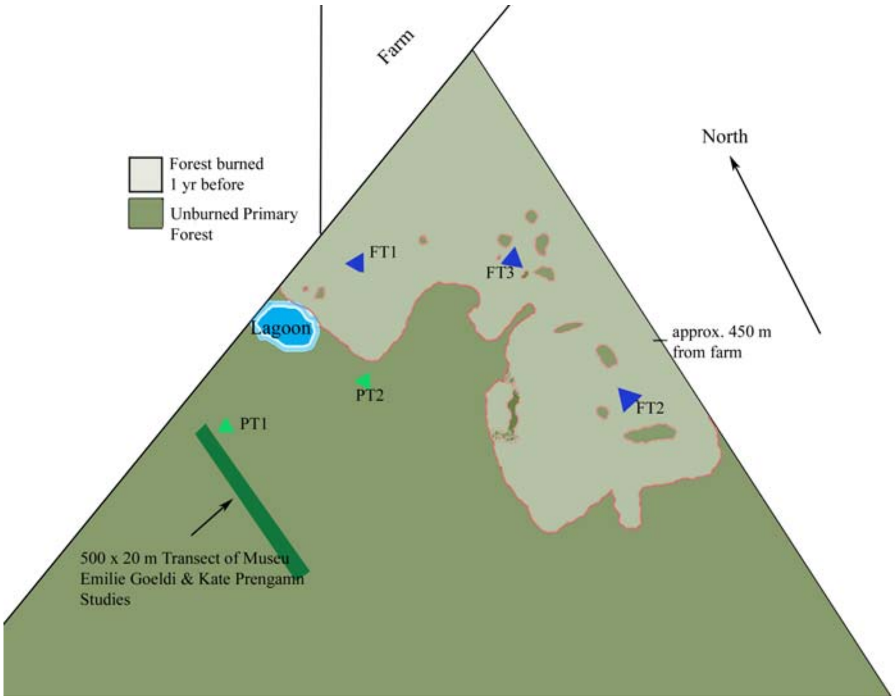
Synopsis:

Fires affect millions of hectares of tropical forests around the world. These fires result in great environmental damage and economical losses. Many farmers are dependant on fire for managing their lands and many times their fires accidentally spread into forest via fuels on the forest floor. This study attempted to analyze and quantify the difference of potential fuel in a primary forest which burned one year before and an unburned part of the same forest at a primary forest fragment surrounded by farms with a history of anthropogenic accidental fires burning it. This was done by making three sample plots in each forest to record the amount of woody materials that cross a linear transect which was made in an equilateral triangle and recording the depth of leaf litter on the forest floor every five meters.

The forest that was sampled was in a fragment of primary terra firma forest near São Fransisco do Pará in Northeast Pará state in a primary forest "characterized as a dense, diverse ecosystem that has had little logging or other damaging effects" (Prengaman citing Almeida, 2002). The edges of the forest have seen many escaped fires from neighboring pastures and farms enter. The forest area sampled burned once one year prior, although other parts of the forest have burned several to unmemorable amounts of times.

Also, because the fire noticeably left the burned forest in several structurally different conditions the three samples of each forest type were compared to understand the significance of the differentiation. The study found the burned forest on average had significantly more available woody material than the unburned forest and most of the additional material was found between 0.5 and 2 meters above the ground; as well as the burned forest had an average leaf litter depth of less than 74 percent compared to the unburned primary forest. However, the study was

Map of Forest Burned 1 Year Prior and Sample Plots



Map of Forest Fragment Studied near São Fransisco do Pará

unable to find a significant difference in the three samples in the three structurally different areas of the burned forest when it was found that there was more of a variation in between the three sample plots in the seemingly structurally similar primary forest.

Introduction:

Fires affect millions of hectares of tropical forests around the world. More than 20 million hectares burned in Southeast Asia and Latin America in the years of 1997 and 1998 alone, and in the year 2000, five million hectares in the Brazilian state of Roraima experienced fire (Cochrane 2003). Although tropical forests have a naturally low risk of catching fire, human disturbance and settlement increase susceptibility with creating edge affects, timber extraction, and supplying the needed initial ignition that a fire needs to begin (Cochrane, 2003). Many farmers are dependant on fire for managing croplands and pastures, and when these fires get out of control they can accidentally enter the forest via the fuels on the forest floor.

Losses in the Amazon as a result of escaped fires from pastures have been incomprehensively estimated to vary varying between US $12-97 million per year (Vera Diaz 2002). Natural fires have been estimated to still account for up 10% of global biomass burning (Crutzen and Andreae, as cited by Stott), and one study of surface fires in eastern Amazonia found that during a severe El Nino event, like that of 1998, could commit carbon emissions equivalent to 10-12.5% of annual global carbon emissions from fossil fuels (Barlow, Peres, Lagam, Haugaasen (2003). The carbon emissions of the El Niño year of 1998 from the Amazon have also been estimated to have had an economic damage of $4.6-4.7 billion (Vera Diaz 2002).

Economic losses to local communities of escaped fires include destroyed crops, pasture, timber, infrastructure, and cattle (Cochrane 2003). Also, after the primary forest burns it is practically useless to the local communities; they no longer are able to hunt there, and when questioned no one in the local community said they even go in them.

Studies on the impacts of these surface fires on the forest themselves have recorded a 51% decrease of live biomass with a Diameter at Breast-Height greater than 10 cm (Barlow *et. al* 2003), large decreases in soil seedbanks contributing to an inability to regain loss species (Cochrane 2003), a diminished presence of forest fauna, a decrease of food for foraging substrate, a decrease of prey items for understroy insectivores, and reduced food supplies for vertebrate frugivores (Peres 1999). Additionally, surface fires leave forests in a state more susceptible for subsequent fires. The mortality of the canopy species increases the amount of canopy gaps which increases the amount of solar radiation, decreases the leaf cover index, and thus decreases the relative humidity and increases the vapor pressure deficit; all of this contributes to drying out the forest making it more susceptible to fire. The high mortality rates of flora after surfaces fires also contributes to a greater amount of Above Ground Dead Biomass which contributes to an increase in the availability of fuel (Peres 1999). This study attempts to understand how a primary forest burned once one year prior by a small surface fire is different in its amount of available fuels to better understand how prone the forest might be to another fire.

A ground survey of the burned area in this study revealed that the forest after the fire did not look uniform. Primary forest in the tropics are extremely diverse ecosystems therefore it is understandable that all parts of the forest would look different after be burned and that all parts of the forest would have different available fuels before and after. To get an idea of the diversity of flora affecting surface fuels for a fire in the examined forest, a study was conducted previously in a part of the forest which is still an unburned primary forest which found in 20 meters 75 different identified leaves leveled to a 70% rate of variability (Prengaman, 2005). So 20 meters from any point would result in a composition with 70% different leaves. Originally the differences in the appearances of the burned forest might have been the direct result of the fuels which burned as the character and ecological significance of a fire is determined by the nature and disposition of its fuels (Stocks and Trollope, 1993 as cited by Stott 2000). The differences of the appearances now could have resulted on how the different fire qualities affected the flora and the affects of this after one year, mainly canopy coverage and how lethal the fire actually was. Because of the varying qualities of fuel and therefore qualities of fire this study also attempts to find if and how amounts of one-year post-fire fuel loads differ within the same area burned by one fire.

Methods:

The forest sampled was in a fragment of primary terra firma forest near São Fransisco do Pará in Northeast Pará state, and the primary forest is “characterized as a dense, diverse ecosystem that has had little logging or other damaging effects” (Prengaman citing Almeida, 2002). However, many areas of this forest have burned from accidental fires. From a not completely extensive ground survey and talks with local community members I was able to find three distinct regions, all adjacent to farms or pastures, which have burned in the past. One is on the western side and burned many years ago which may have been 10 but no one I talked to was sure. Another was on the east side adjacent to a large farm and this region was comprised of many different areas of fire history; some parts of the forest had burned three times and others had burned so many times that no one I talked to knew. The last one was on the northeast side of the forest and was burned one year ago at the end of the dry season, which is the burning season, when a fire accidentally entered the forest from a farm which neighbors it. The area from the fire last year burned on two sides of a road running North-South from the farm, on the East side it burned areas reaching to the areas burned multiple times previously mentioned. The burn on the West side of the road is where I conducted my study.

The fieldwork occurred from 26 November until 2 December 2006. To quantify fuel available equilateral triangles, or **fire triangles**, with 30 meter sides were made with cording, three in the burned area of the forest, and three in areas of primary forest. On each line of the triangle litter depth was recorded at every 5 meters 3 times, once directly under the line and one time one meter to each side, for a total of 18 points (where sides of the triangle met were only recorded once) and 54 measurements per triangle.

Figure 1: Map of Forest Fragment with Burn Areas and Study Area Highlighted

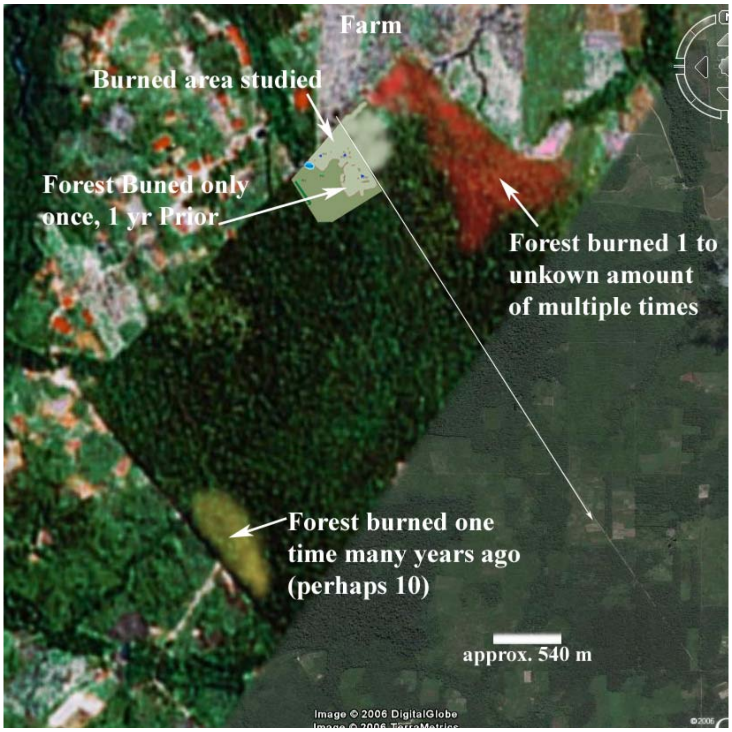
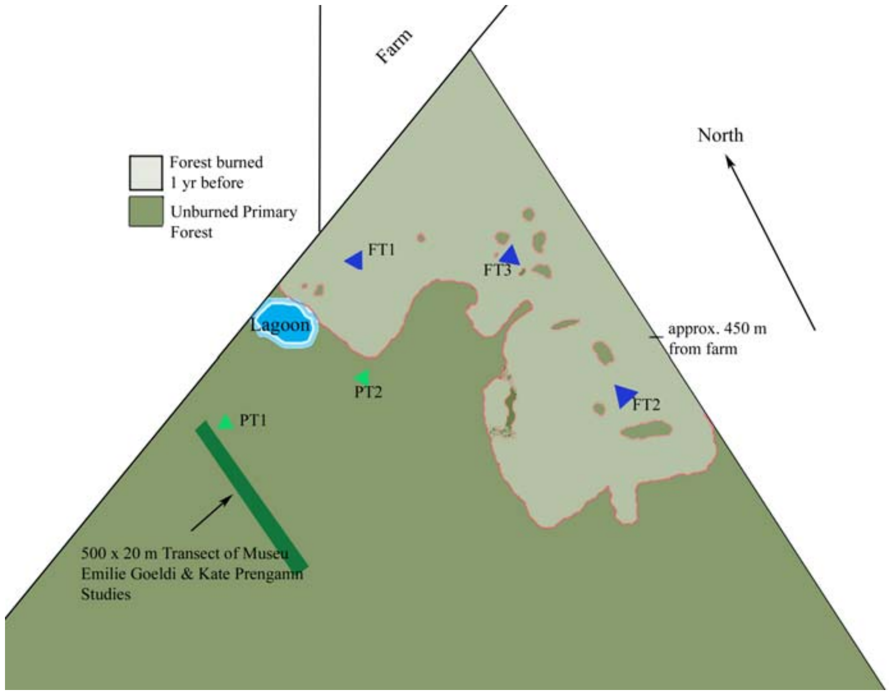


Photo: Google Earth 2006.

Figure 2: Map of Area Burned Once, One Year Ago Studied and Fire Triangle Plots



*FT=Burned Forest **Fire Triangles**. PT=Primary Forest, Unburned, **Fire Triangles** (The 3rd is 1.8 km South from the farm).

Additionally, every piece of potential fuel, in the form of dead and live biomass crossing the cord within 2 meters from the ground was classified by size and height were located and recorded. Live standing biomass like live tree trunks were not recorded, also were never intersected by the lines, but roots and branches which passed under two meters were. The plant materials that crossed the line were classified by diameter into 5 classes: 0-.5 cm, .5-1 cm, 1-2.5 cm, 2.5-5 cm, and a final class of everything >5 cm in which everything in this class had its diameter recorded. The potential fuel was also classified by the height from the ground in which the plant matter was found in 3 classes: between 0-.5 meters, 0.5-1 meter, and 1-2 meters.

Plots for the triangles in the burned forest were chosen randomly within 3 different areas of the burned area: the first made about a hundred meters from the edge adjacent to the farm where the fire came from; the second made far from the farm and about 130 meters from an end of the fire; and the third in between the two. In each relative area the triangles were made in a random spot and choosing a random direction for the first line.

Plots for the triangles for the primary forest were randomly chosen in three different areas. The first was near the 500 x 20 meter plot Kate Prengaman used for her study on leaf litter variability about 500 meters away from the western edge of the burned forest sampled. The second was an area of primary forest relatively near the burned forest, which the triangle ended up being about 50 meters away from the western part of the burned forest. The final primary forest triangle was made in a primary forest about 1.8 kilometers south from the farm where the forest started.

Results:

The fire triangle fuel survey proved that within 2 meters from the ground the forest that burned 1 year previously had more biomass for potential fuel for a fire in the form of sticks, branches, and dead trees but contained less amounts of surface leaf litter. In total number of samples of each categorical size the burned forest had significantly more as seen in **table 1** and **Figure 3.**

Table 1: Total # of Woody Debris Samples Found Less than 2 Meters Above Ground

Diameter of fuel	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-5 cm	>5 cm
Primary Forest	2668	723	336	117	38
Burned Forest	3691	1249	529	219	79
% more fuel in Burned Forest	27.7	42.1	36.5	46.6	51.9

Most of this difference in total number is accounted for between 0.5 and 2 meters above the ground where unburned forests had significantly less potential fuel. Samples with a diameter greater than 5 centimeters were more prevalent less than 0.5 meters high in burned forest, with 70 occurrences, compared to the unburned 38 occurrences. The samples in the burned forest under 0.5 meters had an average diameter of 11.88 centimeters for a total of 831.6 centimeters of diameter whereas the unburned forest's samples had a larger average diameter of 19.61 centimeters for a total of 745.18 centimeters in diameter.

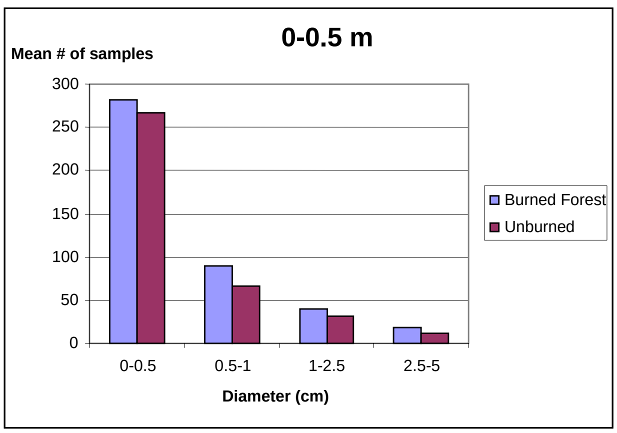
A majority of the difference in total number of potential fuel particles in the burned forest was accounted for within 0.5 and 2 meters above the ground. Between the ground and 0.5 meters above the difference of the means of the burned and unburned forest were relatively small in the fuel biomass with diameters less than 5 centimeters when compared to those found above 0.5 meters. No specimens of diameter greater than 5 centimeters were stratified above 0.5

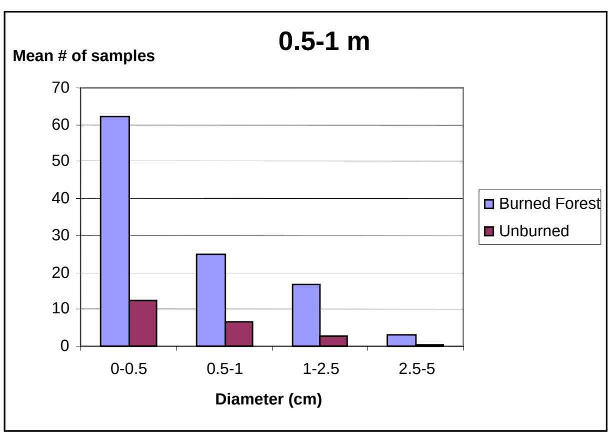
meters in the unburned forest plots, and the burned forest plots had 14 with an average diameter of 6.43 centimeters for a total of 90.02 centimeters of diameter.

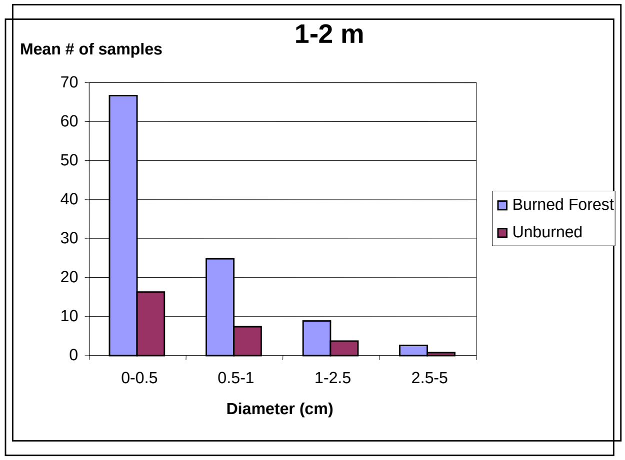
Table 2: Percent More Fuel Particles with Diameter Less Than 5 cm in Burned Forest Means Compared to Unburned Forest Means Depending on Location of Height

	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-5 cm
Within 0-0.5 m Above Ground	4.9	25.5	22.7	36.5
Within 0.5-1 m Above Ground	80	74	84.2	90
Within 1-2 m Above Ground	75.3	69.8	60.5	73.9

Figure 3:Means of Fuel Found with Diameter Less Than 5 cm in Burned and Unburned Plots in Regards To Location Depending on Height







The difference in the leaf litter depth between the burned and unburned forest was found to average more than double in the unburned primary forest. The mean litter depth of the unburned forest was 1.1481 centimeters deep while the depth in the unburned forest was 4.4074 accounting for a 74% difference. In addition, the burned forest had a litter depth of 0 centimeters recorded 32 times out of the 162 measurements (a frequency of 19.8%). Some of these could be accounted for by dead trees lying on the ground without litter on top, which was the case for all 3 recordings of 0 centimeters for the unburned forest, however, most of the times the location of the litter depth measurement was at areas where the surface soil was exposed (Figure 4). This was never encountered in the unburned primary forest. Many times the burned forest had areas without any leaf litter and with exposed surface soil as pictured below.

Figure 4: Exposed Surface Soil in the Burned Forest (near Burned Fire Triangle #1)

Comparison of the Three Different Sample Areas of Burned Forest:

Area around burned forest fire triangle 1:

This area was closest to the farm were the fire originate and appeared to have the most severe damage from the large amount of open canopy and areas of exposed surface soil. It was located about 100 meters away from the farm and most likely was subjected to edge effects. Edges are subjected to stronger winds, which in closed canopy primary forests usually are subjected only to the top of the canopy, increased amounts of sunlight reaching the understory, and structural changes such as increased mortality of trees and decreased living biomass which leads to increased fuel loads of woody debris, all making the edges of the forest more susceptible to fire (Cochrane 2003, Laurance and Williamson 2001). With increased amounts of fuel and a drier environment the edge is not only more susceptible, but also when ignited it has more available fuel with a lower initial ignition temperature.

This difference in severity was observed as the forest visibly had the least amount of standing live or dead trees and the most amounts of areas of exposed surface soil (**Figure 4**). This area also visibly had the tallest and most dense amount of understory growth, which almost all were most likely pioneer species because of the almost total lack of canopy as can be seen in **Figures 4** and **5**. It also had large dense piles of dead woody debris over 2 meters high, and most were overgrown with vines, as were most dead standing trees, as can be seen in **Figures 5** and **6**.

Figure 5: Forest of the First Fire Triangle in the Burned Forest

Figure 6: Area of Burned Forest Fire Triangle 1

Area around burned forest fire triangle 2:

This area was the farthest from the farm which was the start of the fire. Unlike the area of the first fire triangle in the burned forest it visibly had more standing dead and live trees. The canopy was mostly a large gap with scattered live trees to provide limited and sparse cover; however, it was noticeably larger than the almost completely absent canopy of the first triangle near the start of the fire (**Figure 6**). This area had less density of understory growth and most of it was shorter than in the first fire plot. This one also had dense piles of dead woody debris higher than 2 meters and overgrown with vines as well, and also had areas of surface soil exposed.

Figure 6: Forest of the Second Fire Triangle in the Burned Forest

Area around burned forest fire triangle 3:

This area was located in between the other 2 plots in regards the location of the farm, right after a noticeable difference from forest which looked like that of the first fire triangle and before a noticeable difference into a forest which looked like that of the second fire triangle plot. This forest had a thin canopy with many gaps; however, it had the most prevalent canopy and provided the most cover than either of the other two plots (**Figure 7**). It had the most standing live and dead trees out of the three areas, and had the least amount of understory growth and vines. Dense piles of woody debris over 2 meters high as seen in the other areas were absent; the woody debris that was over 2 meters high was sparse and not thickly stacked with large amounts of vines covering it. There were also areas of exposed surface soil.

Figure 7: Forest of the Third Fire Triangle of the Burned Forest

Comparison of the 3 Areas of the Burned Forest:

Out of the three fire triangles the area of the first triangle had the smallest average of leaf litter depth. The mean depths were:

Table 3: Mean Depths of Leaf Litter in the Burned Forest Fire Triangles

Triangles of Burned Forest	Average Depth in Centimeters
Fire Triangle 1	0.6685
Fire Triangle 2	0.9611
Fire Triangle 3	1.8147

The first triangle had a 30.4 percent less average leaf litter depth than the second triangle, and 63.2 percent less than the third triangle. The second triangle had a 47 percent less average leaf litter depth than the third triangle. For perspective the mean leaf litter depth for the triangle in the unburned primary forest was 4.4074 centimeters which is 58.8 percent more than the mean of the third triangle in the burned forest.

For means of woody debris with diameters greater than 5 centimeters there was not a significantly large deviation. The below table is of the total number of woody debris greater than 5 centimeters in diameter, the average diameters, and the total centimeters of diameter in each fire triangle:

Table 4: Number of Woody Debris Greater than 5 cm, Average Diameters, and Total Centimeters of Diameter of the 3 Fire Triangles of the Burned Forest

Burned Forest Triangle	Total # of Woody Debris >5 cm in Diameter	Avg. Diameter	Total Centimeters of Diameter
FT1	27	11.73	316.8
FT2	31	13.2	409.3
FT3	26	8.97	233.21

Because each triangle only covers 90 meters and all three triangles have within five woody debris samples greater than 5 centimeters the significance of the differences is doubtful. However, it is interesting that even though the first triangle has less standing trees it did not have a noticeably larger amount, and indeed had less than the second triangle in the burned forest.

For means of woody debris found and height there were only small significances within the displacement of height and number of woody debris characterized by diameter as can be seen by **Table 5**. However, it is interesting to note that like the woody debris with diameters greater than 5 centimeters the third fire triangle has the least amount total mean samples for each diameter class from the ground until 2 meters above.

Comparison of the Three Different Sample Areas of Primary Forest:

Unlike the burned forest which had strikingly noticeable different compositions, the three unburned primary plots had a similar structure even though one of them was about 2 kilometers away from the other two. They all where characterized by a tall well-covering canopy, an easily navigatable understory although dense enough with leaves to severely limit visibility past 10 meters, a great lack of chirica (sic) and other thorny plants compared to the burned forest, much less solar radiation (the floor was almost completely shaded), and a more moist and cooler environment (**Figure 8**).

Between the 5 different diameter classes for the woody debris there was found to be more variation within the 3 primary forest fire triangles than the three burned forest fire triangles. Even within the 2 triangles which were distanced in a distance relatively the same as the fire triangles from each other (PT1 and PT3) there was seen to be a much larger variation (**Table 6**).

Figure 8: Primary Forest with a Line of a Triangle

Table 5: Mean Numbers of Woody Debris of Each Fire Triangle in the Burned Forest Classified by Height Found Above Ground and Diameter

Diameter	Height Above Ground	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-5 cm
FT1	0-0.5 m	345.67	84	27.67	24.33
	0.5-1 m	73.33	35.33	33	2.67
	1-2 m	39	32.33	7.33	3
	Total #	**458**	**151.66**	**68**	**30**
FT2	0-0.5 m	202.33	93.67	45.33	16.33
	0.5-1 m	67.67	30.33	14	6
	1-2 m	124	37	16.67	2
	Total #	**394**	**161**	**76**	**24.33**
FT3	0-0.5 m	294.67	89.33	47.67	15
	0.5-1 m	45.33	8.67	3.67	1
	1-2 m	36.67	5.67	3	2.67
	Total #	**376.67**	**103.67**	**54.34**	**18.67**

Characteristics the three plots shared included that the large majority of all woody materials found in all 5 diameter classes were found within the first 0.5 meters of the ground. As the diameter increased there was less woody debris available, and there was no debris with a diameter greater than 5 centimeters 0.5 meters above the forest floor.

Table 6: Mean Numbers of Woody Debris of Each Fire Triangle in the Unburned Primary Forest Classified by Height Found Above Ground and Diameter

Diameter	Height Above Ground	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-5 cm	> 5 cm	Average Centimeters of Diameter (for those >5 cm)
PT1	0-0.5 m	354.33	63.33	39.33	10	16	27.59375
	0.5-1 m	8.67	6.33	2	0	0	
	1-2 m	14.33	3.67	0.67	0	0	
	Total #	**377.33**	**73.33**	**42**	**10**	**16**	
PT2	0-0.5 m	216.67	76	27.67	16.67	14	16.31429
	0.5-1 m	6.33	8.33	4	0.67	0	
	1-2 m	11	17.67	6.33	0.67	0	
	Total #	**234**	**102**	**38**	**18.01**	**14**	

PT3	0-0.5 m	231.67	59.67	26.33	8.67	8	9.4125
	0.5-1 m	22.33	4.67	2	0.33	0	
	1-2 m	24	1.33	3.67	1.33	0	
	Total #	**278**	**65.67**	**32**	**10.33**	**8**	

The three plots also had relatively similar mean leaf litter depths when compared to the plots of the burned forest. The largest deviation is only 34.1 percent whereas the smallest deviation in the burned forest was 30.4 percent (the largest being 63.2 percent). Unlike the burned forests, exposed soil on the forest floor was never encountered.

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Table 7: Mean Leaf Litter Depths of the Unburned Primary Forest Fire Triangles

Fire Triangle	Average Leaf Litter Depth (cm)
PT1	3.9352
PT2	3.6907
PT3	5.5963

<u>Analysis:</u>

An increased amount of biomass in the form of woody debris in a primary forest burned by a surface fire one year before was found in the sample plots of the burned forest when compared to plots in the adjacent remaining unburned primary forest. Although there was a reduction in leaf litter depth on average of 74 percent in the burned forest, the burned forest had an increased amount of small woody materials: on average 27.7 percent with a diameter between 0 and 0.5 centimeters, 42.1 percent with a diameter between 0.5 and 1 centimeters, 36.5 percent with a diameter between 1 and 2.5 centimeters, and 46.6 percent between 2.5 and 5 centimeters. Even thought the primary forest has larger diameters for its woody items found with diameters greater than 5 centimeters these are most likely not going to be able to burn as well as smaller diameter woody items because they are able to contain large amounts of moisture. These smaller woody materials are important contributors to further ignition and combustion (Stott 2000). Because all of the areas of the burned forests had either a very thin canopy or almost none at all these woody materials are subjected to the increased access of otherwise the mostly stagnant wind of the understory of a primary forest, and almost all are subjected to direct solar radiation for at least a part of the day when otherwise they would be under a dense canopy, they are able to maintain less moisture internally and so they are drier and have lower temperatures needed for ignition. Woody material begins an exothermic reaction just above 300 °C (Stott 2000). Thus combustion of these materials would have a high temperature and plenty of other dry woody materials nearby which would fuel the subsequent more intense fire. Therefore the increased fuel load interacting with the new forest structure has made the forest in state more susceptible to fire and which would be more intense.

Additionally, as this study attempted, being able to find how amounts of fuel a forest one year after a surface fire differs within a single burned area over distances was not accomplished. Although different areas of the burned forest are noticeably different in structure and appearance the 3 studied plots ended up being more homogenous in regards to amounts of woody material fuels than the 3 primary forest plots which all appeared to have a very similar structure. In the end there was not enough sample plots to truly understand this variability. As the three primary forest plots differed in the fuel below 0.5 meters, the fuel which would burn in a surface fire like the one which burned the studied forest, one would expect the fires to result to differ as well because the character and ecological significance of a fire is determined by the nature and disposition of its fuels (Stocks and Trollope, 1993 as cited by Stott). As these differences in original fuels, and thus character and ecological significance of their fires, they would most likely shape the character and ecology of the forest which remains after the fire. Therefore the variability of the original fuels would determine what the fuel load of that forest would resemble after a fire.

Conclusions:

This study was able to comparatively quantify an amount of potential fuel in the forms of woody debris and leaf litter between a primary forest and a part of that same forest which had burned one year before. The results solidified the hypothesis that a tropical primary forest would have more potential fuel for a fire one year after a fire. Additionally, with the qualitative ground survey of the burned forest it can be expected that it is more susceptible to fire because of the massive damage inflicted on the canopy and its increased load of Above Ground Dead Biomass. Every studied plot of the burned forest when compared to any of the unburned plots was able to show a higher amount of available fuel. However, each part of the burned forest was noticeably different in appearance and quality of fuel loads. This most likely has to be a result of the variance in the original fuel load of the primary forest which is described by the vast biodiversity which tropical rainforests are composed of, by Prengaman's study (2005) which found in the same forest a variance of 70 percent in the composition of leaves on the forest floor within 20 meters during the dry season, and with this study which found a greater variance in similarly structured primary forest fuel loads than in the noticeably different looking burned forest fuel loads.

This paper was able to identify that a variance in fuel loads exists in this primary forest, and that fuel loads vary (although less than primary forest in this case) and structure of in burned primary forests. This variance in fuel loads in burned and unburned forest would be important to know to better understand how tropical forests burn. If limits of the variance of fuel loads can be found maybe it would help better create a more realistic model for how tropical forest fires burn. If the fuel loads in primary forests not only vary in composition of amounts of fuel but also in chemical composition as Prengaman (2005) found in a preliminary test of the combustion of the leaves which make up the primary forest fuel loads, the variances of both the amounts and the chemical compositions should be identified and understood how they interact.

<u>References:</u>

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Appendix I: Primary Forest Fire Triangle Data

Primary forest plot 1 (PT1)						Leaf Litter Depth (cm)	**Sample** 1	2	3
	Diameter					**M of Measurement**			
SIDE A	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	0	1.2	2.5	3.7
Height									
0-0.5 m	449	94	35	5	6.2, 180, 8.7, 35.4, 11.3	5	2.5	14	2.2
0.5-1 m	15	6	2	0	0	10	2.1	8.1	12.2
1-2 m	6	1	0	0	0	15	2.5	8.6	3.4
						20	3.8	3.1	6
						25	2.4	3.9	1.5
						30	3.7	2.1	4.3
SIDE B	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	312	53	46	14	7.2, 28.6	0			
0.5-1 m	3	11	2	0	0	5	3.3	0.3	8.6
1-2 m	24	6	0	2	0	10	2.5	5	4.4
						15	7.5	8.7	5.1
						20	2.1	0.5	2.4
						25	0.1	2	2.4
						30	1.1	1.7	1.3
SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	302	43	37	11	22.9, 29, 15.2, 29,	0			

					7.5, 37.4, 8.4, 7, 7.7				
0.5-1 m	8	2	2	0	0	5	1.1	2.7	4.5
1-2 m	13	4	2	0	0	10	4.1	5.2	2.7
						15	1.8	2.2	3
						20	7.5	1.6	6.6
						25	5.2	3.4	8.1
						30			
Primary forest plot 2 (PT2)									
SIDE A	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)	**Saple**		
Height						**M of Measurement**			
0-0.5 m	204	76	29	24	6.2, 15, 7.7, 51.4	0	0.4	4.1	4.3
0.5-1 m	7	5	3	0	0	5	6.1	4.3	2.5
1-2 m	2	30	12	0	0	10	1.6	0.7	0.2
						15	0.2	1.6	3.6
						20	1.1	2.4	7.3
						25	7.9	3.4	4
						30	3.1	0	3.4
SIDE B	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	204	70	28	14	19, 7.4, 6.9, 7.2	0			
0.5-1 m	4	13	8	1	0	5	7.9	5.9	5.6
1-2 m	17	9	1	0	0	10	4.1	3.1	5.1
						15	3.3	0.2	4.4
						20	4.1	0	7.3
						25	4.1	3.9	3.2
						30	10.1	5.5	2
SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm				
0-0.5 m	242	82	26	12	6.8, 13.9, 6.3, 64.4, 9.5, 6.7	Leaf Litter Depth (cm)			
0.5-1 m	8	7	1	1	0	0			
1-2 m	14	14	6	2	0	5	1.6	6.9	4
						10	2.4	4.9	0.3
						15	4.2	4.1	3.1
						20	2.1	3.2	5.1
						25	4.5	3.9	7
						30			
Primary forest plot 3 (PT3)									
SIDE A	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)	**Sample**		
Height						**M of Measurement**			
0-0.5 m	208	65	29	12	6.4	0	7.1	1	2.4
0.5-1 m	37	9	4	0		5	7.3	3.4	7.5
1-2 m	42	0	6	0		10	3.3	4.5	0.9

							15	5.7	9.3	10.5
							20	2.5	9.6	4.7
							25	5	10.5	3.4
							30	2.6	3.5	3.7

SIDE B	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	201	51	14	6	5.9, 11, 5.4, 5.3	0			
0.5-1 m	16	4	1	1		5	5.1	4	3.4
1-2 m	18	3	4	4		10	7.5	5.6	3.2
						15	7	6.8	3.5
						20	5.5	0	6.8
						25	0.4	2.5	7.3
						30	4.6	6.6	6.8

SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	286	63	36	8	6.2, 23.1, 12	0			
0.5-1 m	14	1	1	0		5	3.5	3	5.2
1-2 m	12	1	1	0		10	3.7	3.1	4
						15	2	11.6	3.2
						20	4.1	5.5	5.1
						25	2.5	5	7.4
						30			

Total Average # for All Primary Forest Plots

Height	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	*>5 cm (Avg Diameter)	Leaf Litter Depth (cm)
0-0.5 m	267.5567	66.3333	31.11	11.78	19.6105	4.4074
0.5-1 m	12.4433	6.4433	2.67	0.3333	0	
1-2 m	16.4433	7.5567	3.5567	0.6667	0	
Total # of samples between 0.5-2 m	2668	723	336	117	38	

*Meter of Measurement is location on the fire triangle where leaf litter depth measurements were taken.

Appendix II: Burned Forest Fire Triangle Data

Fire forest plot 1

SIDE A **Height**	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm) **M of Measurement**	**Sample** 1	2	3
0-0.5 m	408	72	19	30	27.2, 7.7, 4.6,		0.4	1	0

					4.7, 4.1, 12.1		0			
0.5-1 m	67	28	5	3	0		5	0.1	0.3	1.9
1-2 m	24	16	6	6	6.8, 8.6		10	0	0.4	0.2
							15	0.2	0	0.6
							20	0.6	0.3	1.1
							25	0	0.1	0.1
							30	0	0	2
SIDE B	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)		1	2	3
0-0.5 m	371	96	37	16	27.9, 10.4, 5.8, 6.4, 12.3, 72.9		0			
0.5-1 m	75	38	21	2	6.8		5	0.1	0.2	0
1-2 m	70	33	6	3	0		10	1.1	1.6	1.7
							15	2.4	1.2	3.5
							20	3.1	0	0.6
							25	2.1	2.6	0
							30	0	0.4	0
SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)		1	2	3
0-0.5 m	261	84	27	27	5.9, 6, 13.3, 23.7, 5.4, 5.8, 8.1		0			
0.5-1 m	78	40	7	3	5.9, 6.2		5	0	0	0.8
1-2 m	23	48	10	0	6.1, 5.6, 6.5		10	0	0.4	0.6
							15	1.2	0	3
							20	0	0.3	0.8
							25	0	0	0.1
							30			

Fire forest plot 2										
SIDE A	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)		**Sample**		
Height							**M of Measurement**			
0-0.5 m	250	88	36	19	19.1, 5.4, 8.3, 16.5		0	0.2	0.1	0
0.5-1 m	55	25	10	3	0		5	2.9	0.6	8
1-2 m	55	34	14	0	0		10	0	0.7	0
							15	0.6	3.2	0.2
							20	1.1	2.6	1
							25	1.4	0	0.7
							30	0.4	0.3	0.7
SIDE B	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)				
0-0.5 m	246	92	48	17	5.9, 9.1, 17.4,		0			

					58, 6.7, 5.8, 5.3				
0.5-1 m	61	45	11	11	0	5	21.7	0.2	0.3
1-2 m	215	61	20	5	5.2	10	0.1	0.6	0.2
						15	0	0.1	0.1
						20	0.4	0.1	3
						25	1.1	0	0.5
						30	3.1	0.9	0
SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
0-0.5 m	113	101	52	13	8.2, 15.5, 13.4, 5.9, 27.6, 7, 11.3, 8.5, 21.9, 5.3, 24, 7.7, 11.4, 21.6, 9.4, 27.6, 6.9, 6.3	0			
0.5-1 m	87	21	21	4	0	5	0	2.8	0.1
1-2 m	102	16	16	1	7.1	10	0	0.2	0.5
						15	0.1	0	4
						20	1	0.5	0.7
						25	0	1.2	0.4
						30			

Forest fire plot 3

SIDE A	**Diameter** 0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)	**Sample**		
Height						**M of Measurement**			
0-0.5 m	237	83	32	18	10, 8.9, 6.1, 5.4, 6.1, 11.3	0	5.5	4.7	0.6
0.5-1 m	13	5	4	1	6.2	5	1.4	1.8	6.7
1-2 m	5	3	2	1	8.4, 5.5, 5.1	10	0.8	0.3	1
						15	0	2	0.3
SIDE B						20	0.1	0.2	1.7
0-0.5 m						25	1.8	3.5	1.6
0.5-1 m						30	0.1	6.3	0
1-2 m	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)			
	309	97	55	15	6.6, 8.4, 8, 7.4, 26.9	0			
	62	11	6	2	0	5	0.1	0.9	1.1
	51	2	1	7	0	10	2.4	0.1	1.2

SIDE C	0-0.5 cm	0.5-1 cm	1-2.5 cm	2.5-cm	>5 cm	Leaf Litter Depth (cm)				
							15	0.4	0.2	0
							20	1	2.5	1.3
							25	4.5	3.1	1.3
							30	1.4	1	2
0-0.5 m	338	88	56	12	9.2, 6, 16.7, 6.9, 14.7, 11.6		0			
0.5-1 m	61	10	1	0	0		5	0.2	4.4	2.1
1-2 m	54	12	6	0	0		10	4	5.1	4.5
							15	0	1	1.8
							20	0	2	6.4
							25	0	0.2	1.4
							30			

Total Average # for Burned Forest Plots

	Diameter 0-0.5	0.5-1	1-2.5	2.5-5	*>5 cm (Avg Diameter)	Fuel depth
Height						
0-0.5 m	281.2233	89	40.2233	18.5533	12.64	1.1481
0.5-1 m	62.11	24.7767	16.89	3.2233	6.275	
1-2 m	66.5567	25	9	2.5567	6.49	

Total # of samples between 0.5-2 m	3691	1249	529	219	79